Localisation and evacuation of travellers in emergency situations: The SAVE ME Project

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Abstract
In this work we demonstrate a proprietary localisation system based on IEEE 802.15.4 wireless technology capable of localising and tracking traveller movements in emergency situations. We also discuss the SAVE ME project as a whole as a method of evacuating travellers in transportation hubs utilising a variety of ITC technologies.
Keywords:
Traveller evacuation, Indoor localisation, Zigbee, IEEE 802.15.4, SAVE ME

Introduction

Public Transport plays a critical role in transportation systems and is essential to the national economy and the social quality of life of citizens. However natural disasters (primarily earthquakes and tsunamis leading to devastating floods) are becoming all the more frequent across the World. These disasters can have serious impacts on transport infrastructures and operations, not just in the short-term timeframe of the disaster itself, but longer term through the recovery process and subsequent rebuilding of the infrastructure.
Another great menace of our time is the increased threat of terrorism. Recent events have demonstrated how Public Transport infrastructures, hubs and stations are often key targets of terrorist attacks. Terrorism hinges on its ability to destroy peoples' trust in the predictability of their environment. While terrorism first and foremost claims lives, its effect is also based on a manipulation of peoples' fears as they do not know when or where the next attack will come and are often unfamiliar with how to protect themselves and those close to them, should such a terrorist attack occur. It has been shown that self-evacuation is often the best way of escaping from a terrorist attack and minimising the loss of life, however people are often rendered powerless in a situation which they cannot control, which is hard to accept.

The EU FP7 funded project SAVE ME aims to develop an intelligent sensor based system designed to help address these issues. The system comprises a number of interrelated components, including a propriety environmental wireless sensor system which detects the nature and location of natural and man-made (i.e. terrorist attacks) disaster events in Public Transport terminals and critical infrastructures, a localisation system based upon the a IEEE 802.15.4 proprietary protocol which identifies the position of travellers within the infrastructure using specifically designed wireless sensor nodes (WSN), and a Decision Support System (DSS) which determines the optimum evacuation strategy based on a combination of real-time information feeds and pre-defined evacuation strategies.
The ultimate aim of SAVE ME is to support the quick and efficient mass evacuation guidance in the event of an emergency, to save the lives of the general public and the rescuers, giving particular emphasis to the most vulnerable travellers (i.e. children, older travellers and the mobility impaired).
The overall system was trialled and tested with participants in two distinct locations, the Colle Capretto rRoad Tunnel, near Perugia in Italy, and also at Monument Metro Station in the centre of Newcastle upon Tyne, UK.

SAVE ME System Architecture

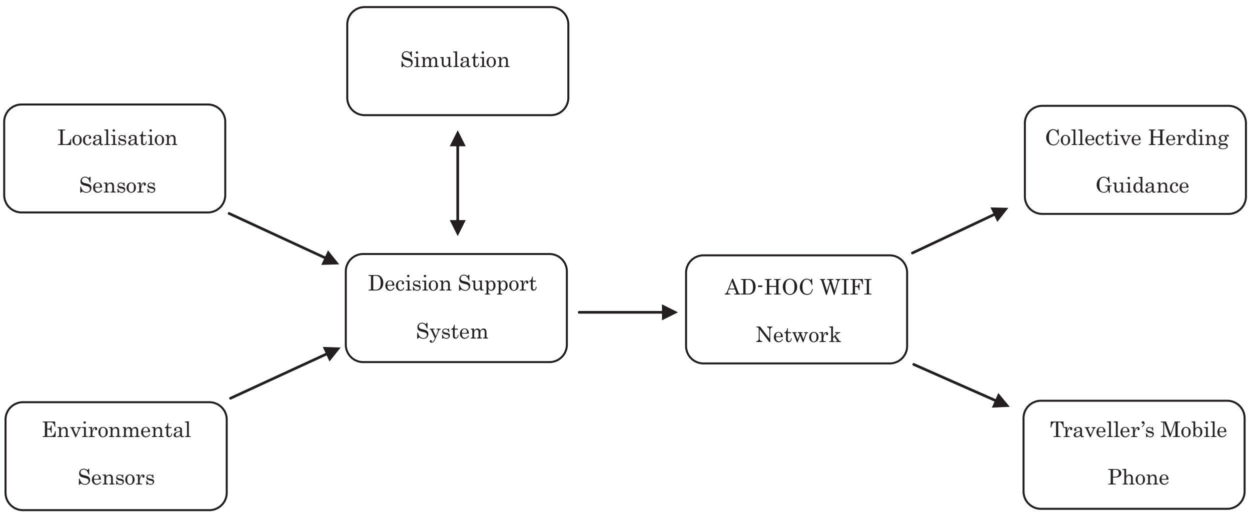

Figure 1 - Simplified Architecture of SAVE ME System

A simplified version of the SAVE ME architecture is shown in Figure 1. Whilst this paper will concentrate primarily on the traveller localisation aspect, we will briefly describe each system component and their functions:
Localisation WSN
As described previously, the localisation system is based on a proprietary 802.15.4 RF protocol and utilizes a Zigbee wireless mesh network for communications, comprising mobile

devices (carried by travellers) and static nodes which are part of the SAVE ME infrastructure and a wireless sink node which in this case was a laptop PC. Its function is to estimate traveller locations and send this information to the DSS. There is also a separate rescuer localisation system which operates in a similar fashion which has been omitted from the architecture for simplicity.

Environmental WSN

A wireless mesh network comprising of multiple proprietary environmental sensors. Its function is to monitor the environment for signs of an emergency and pass the information to the DSS.

Decision Support System

This module is central to the SAVE ME system, its function is to gather the information sent from both the localisation and environmental systems, communicate with a simulation module, and generate safe evacuation plans which are then transmitted to travellers' mobile phones.

Simulation

The simulation module works in conjunction with the DSS, it predicts traveller evacuation routes and potential hazards utilised by the DSS during the generation of evacuation routes. It also provides a 3D visualisation of the travellers and their environment.

AD-HOC Wi-Fi Network

This network provides the backbone communication system to transmit evacuation data to the travellers' Wi-Fi enabled mobile telephones. It is a Better Approach To Mobile Ad-hoc Networking (B.A.T.M.A.N) based protocol of wireless routers providing a Wi-Fi network for any Wi-Fi enabled device.

Collective Herding Guidance

Collective Herding Guidance was implemented using dynamic signage, while multiple signage products exist on the commercial markets, in this work we demonstrate dynamic signage utilising iPads as they incorporate a high definition screen, are WiFi enabled and have an autonomous power supply..

Traveller's Mobile Phone

A SAVE ME application was developed for iPhones, Android based smart phones and Symbian based smart phones. This provides the travellers with the evacuation plans which are communicated over the Wi-Fi network previously mentioned.

Relative Signal Strength Indication (RSSI) as a potential method for indoor localisation

The literature reports numerous examples of localisation methods based on signal strength of various RF frequencies [1-3], 2.4GHz was ultimately selected in this study as it is a widely used, low-power wireless technology designed for wireless mesh networks. Although we have used a 802.15.4 proprietary protocol in our implementation of an indoor localisation system, we acknowledge that giving members of the public extra hardware for the purpose of location tracking would be both intrusive and unfeasible, and present a method of localisation which is compatible with the various wireless technologies built into a modern smart phone.

As reported in the literature, localisation based on the RSSI of any RF frequency is subject to limitations which include the variation in the RSSI due to the environment [4]. In this work the proprietary 802.15.4 RF communications operate around the 2.4GHz frequency range and the RF signal strength is adversely affected by both the presence of water and the inclusion of metal objects. This can affect the effective distance that these wireless devices can communicate with each other and also lead to erroneous readings.

We selected the proprietary 802.15.4 protocol over the inbuilt Bluetooth communications of modern smart phones due to the hurdles presented related to the method by which Bluetooth discovery operates. Bluetooth has 79 independent channels which a device can be on at any given time, in normal operation devices exchange a data packet and then simultaneously hops through the different frequencies of channels to communicate with each other. As a direct result of this architecture it takes a device just over 10 seconds to complete a full scan of all the channels to identify all devices within range. This clearly has disadvantages in terms of real time tracking if the full frequency range is to be covered in each discovery cycle. Despite these drawbacks, the widespread adoption of Bluetooth into a variety of personal electronic devices allows a rough estimation of an individual’s location to within a radius of 5 metres. Furthermore Bluetooth enabled devices are willing to provide limited information to any system through their discovery mode which includes RSSI and a unique MAC address for purposes of identification. At the point at which this data is exchanged, the two devices are still unconnected which poses little risk in terms of data security [5].

In this project, custom WSNs were commissioned in order prove the concept of traveller location and identification within emergency situations. The travellers’ locations are then sent to the DSS, which can provide evacuation plans tailored to the individual’s requirements which are transmitted directly to the individual utilising an ad-hoc Wi-Fi network. The system continuously updates location information and so the evacuation plans are reviewed, recalculated and retransmitted depending upon each individual’s location.

System design

The localisation system consists of a number of Static Units, Mobile Units and a Gateway PC. The Static Units are fixed to the walls at a height of 2m and spaced approximately 10m apart within the infrastructure. Both the Mobile and Static Units share a common hardware design. A RF Solutions PIXIE module provides the range finding and microcontroller functions, this comprises of a Texas Instruments CC2420 2.4GHz IEEE 802.15.4 transceiver with PCB antenna and a Microchip PIC18LF4620 8-bit microcontroller. The CC2420 was selected to handle the physical and MAC layers of the IEEE 802.15.4 proprietary protocol which through the use of the received signal strength indication (RSSI) estimates range.

This proprietary protocol makes use of the smallest possible IEEE 802.15.4 packet size with the CC2420 appending the RSSI value to the end of any received packets. Carrier sense multiple access (CSMA) mode is enabled on the transmission from the CC2420 to avoid collisions on the shared radio channel. A linear feedback shift register (LFSR) is used as an efficient method of providing randomised timing between packet transmission attempts. The LFSR is seeded with the unique device ID to ensure that the pseudorandom sequence is different on each unit.

A Digi XBee ZB module provides the ZigBee on IEEE 802.15.4 physical and MAC layers which are used as the communications backbone for transmitting the range data back to the Gateway PC. For simplicity the two radio systems are physically separated and active on different channels within the 2.4GHz ISM band. A simplified schematic is shown in Figure 2.

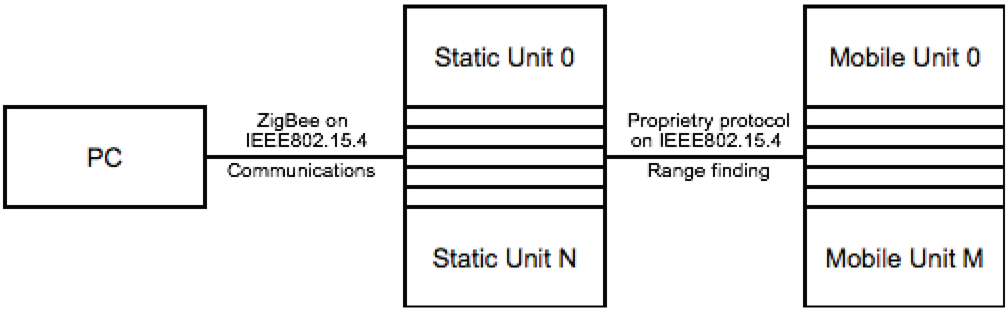

Figure 2 - Simplified System Diagram

The localisation algorithm uses the RSSI values of a number of short broadcast packets from Mobile to Static Units and vice versa to calculate a relative ratio between a Mobile Unit and the nearby Static Units. The Gateway PC software receives the data from each of the Mobile and Static Units via the XBee ZigBee network. This incoming data is queued up and then periodically processed.

A map containing pairs of device IDs and averaged RSSI values is maintained and updated for each incoming data packet in the queue. Thereafter, for each Mobile Unit in the system all the pairs to Static Units with valid RSSI values are then processed to calculate a ratio for each Static Unit. These ratios are then applied to the positions of the Static Units and summed to form the determined position of the Mobile Unit.

Results

Shown in Figure 3 is the average RSSI of a mobile node at a given distance from a static node reported by the system. It can be seen that although the RSSI value fluctuates due to environmental factors there appears to be a linear tread up to 10m, allowing the system to calculate the distance from individual nodes with increased accuracy at lesser distances.

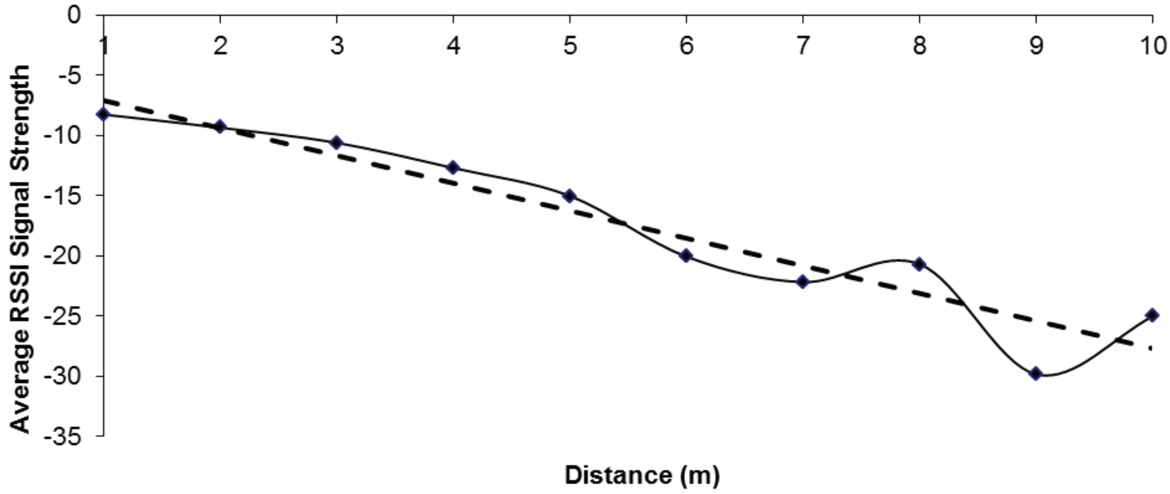

Figure 3 – Average RSSI Signal Strength as a function of distance

Figure 4 depicts the data collected from a linear topology of static nodes i.e. a tunnel environment. Static nodes were placed every 10m up to a distance of 70m and a simulated traveller starting at the furthermost node (70m), can be tracked walking through a tunnel, giving the DSS and other SAVE ME components an indication of the traveller's location in almost real time.

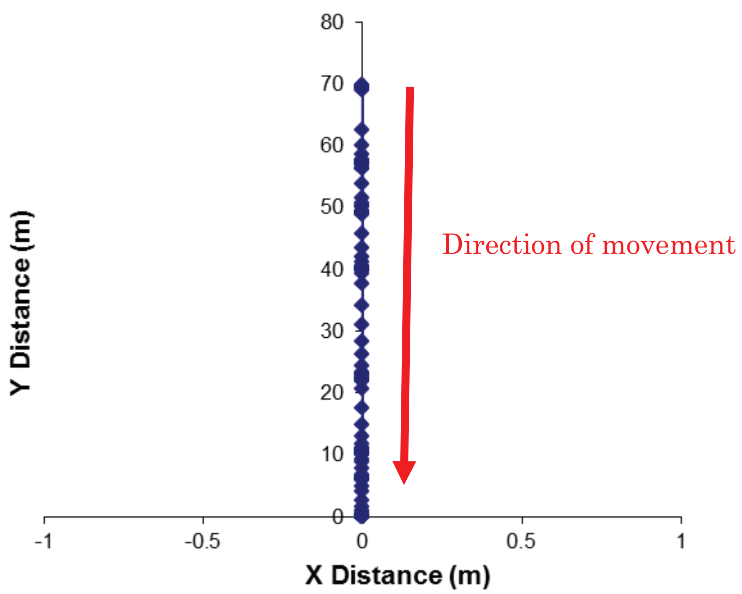

Figure 4 – Linear Localisation Dataplot

Figure 5 shows a photograph of one of the SAVEME trialists mobile phone guidance map from the Monument Metro demonstration.

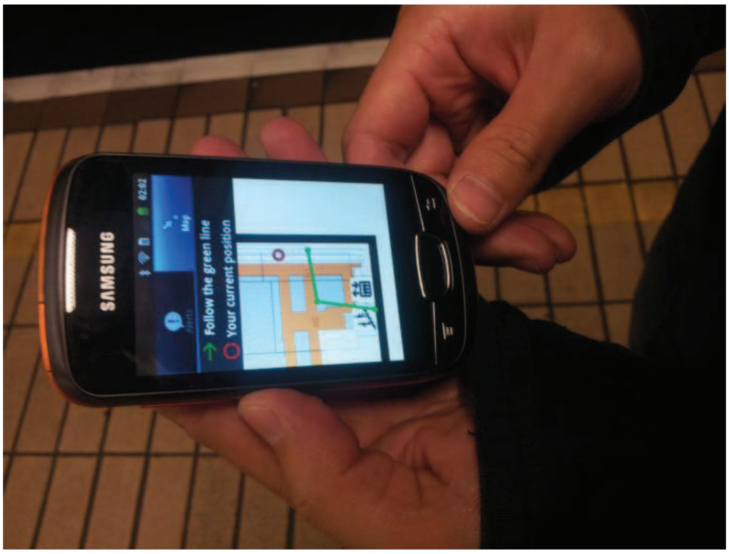

Figure 5: Mobile Phone from Monument Metro Demonstration.

The data shown in Figure 6 depicts the system operation when used in a 2-dimensional topology such as that used within Monument Metro Station. Eight nodes were placed at a distance of 10m from each other around the perimeter of a 20 x 20m square. The data shown is the path of a traveller walking within the perimeter of the square thus demonstrating the system's ability to track travellers whereabouts within a 2-dimensional space.

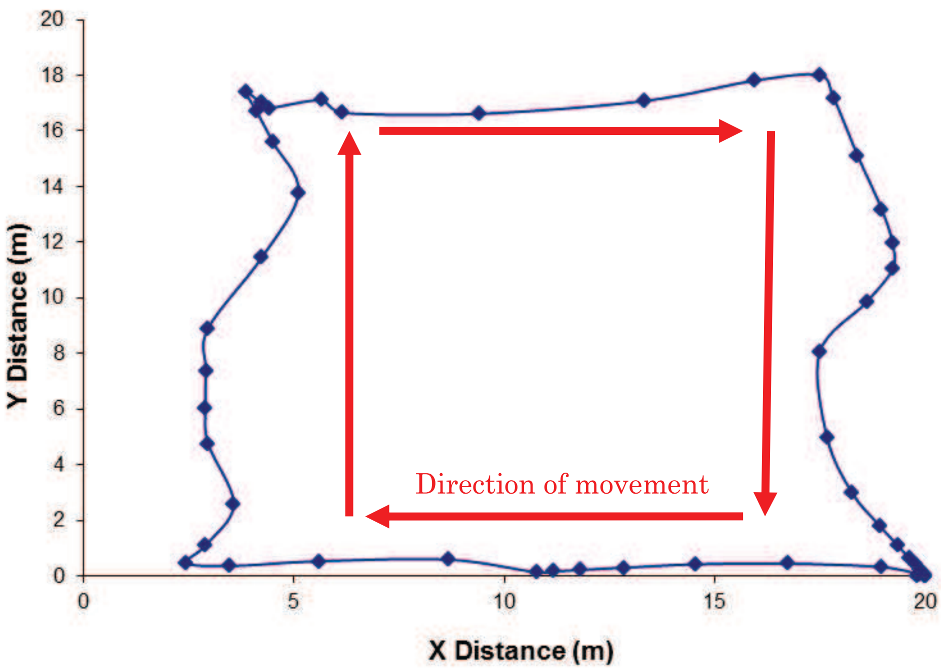

Figure 6 – 2-Dimensional Localisation Dataplot

Conclusions

We have developed and demonstrated a localisation technology based on the RF RSSI values of a proprietary 802.15.4 protocol and integrated its positional data into the SAVE ME system thus providing travellers with an advanced evacuation plan for transportation hubs. The system also provides members of rescue teams with an indication of where travellers are located allowing for faster, safer and more efficient evacuation in the case of an emergency.
Whilst the system required users to carry custom made hardware the methodology is applicable to RSSI values of other RF signals potentially allowing travellers to be tracked using technology that most people carry i.e. the mobile phone.

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